A STUDY OF THE BIOLOGY OF CHELONELLA SULCATA NEES (HYMENOPTERA: BRACONIDAE)

ALBERT ABDEL-MALEK[1]
The Ohio State University,
Columbus, Ohio

INTRODUCTION

Chelonella sulcata Nees is a braconid belonging to the subfamily *Cheloninae*. It is a parasite of some of the most notorious cotton pests in Egypt (e.g., *Platyedra gossypiella* Saunders, *Ephestia kuehniella* Zeller and others). No important studies have been made on this species. This report represents a laboratory study of the biology of *Chelonella sulcata* Nees in Egypt.

The host used in this study was *Ephestia kuehniella* Zeller. *Chelonella sulcata* also was reared successfully in the laboratory from *Earias insulna* Bois., and *Platyedra gossypiella* Saunders.

MORPHOLOGY

Egg—(Pl. I. 1, 2). The length of the egg at oviposition equals 0.154 mm. and the width is 0.0567 mm. The egg of *C. sulcata*, immediately after deposition inside an *Ephestia* egg, is cylindrical, arcuate, or kidney-shaped. It is translucent, white in color, and has a smooth, glistening surface. As development proceeds, the egg becomes distended and the cephalic end broadens, but the length remains the same.

First-Stage Larva—(Pl. I. 3, 4). At eclosion the length is 0.36 mm., the head width 0.084 mm., the first thoracic segment width 0.062 mm., the first abdominal segment width 0.059 mm., and the length of the mandible 0.04 mm.

When 12 days old the total length is 0.084 mm., the head width 0.08 mm., the first thoracic segment width 0.24 mm., and the first abdominal width 0.23 mm.

The newly-hatched larva has a creamy-white body with eight well defined segments, the first of which is very large in proportion to the rest of the segments, and represents the head. This rather square head is followed by three thoracic and four distinct abdominal segments. The last abdominal segment is two times the length of any of the other segments and may be regarded as a division, since it probably represents several true, but as yet undifferentiated, segments. The anal segment is further lengthened into a blunt appendage.

The 12-day old larva differs considerably from the newly hatched larva. The head remains nearly the same size, while the body segments have enlarged. There are three thoracic and six abdominal segments. The first thoracic segment is relatively large and is at least 3.5 times as long as either of the following two segments. This segment probably represents the first thoracic segment since it does not further divide. The last abdominal segment is nearly five times as long as any of the other abdominal segments and bears on its dorsal surface a cap-like swelling which later continues to evaginate to form the anal vesicle.

Second-Stage Larva—(Pl. I. 5). Larval length near the end of this stage is 3.15 mm., greatest width 0.84 mm., head width 0.52 mm., length of mandible 0.10 mm.

[1]I wish to express my sincere gratitude to H. C. Efflatoon Bey, Professor of Entomology, Fouad Ist University, Egypt, to whom I am indebted for this problem and for his helpful suggestions and supervision. Appreciation is expressed to Dr. M. Kamal, Head of Insect Research Laboratory, Ministry of Agriculture, Egypt, for the use of the laboratory in which the present work was done; and to Dr. M. Hafez, Lecturer of Entomology, Fouad Ist University, Cairo, Egypt, for his many helpful suggestions and advice.

I also wish to thank Dr. Alvah Peterson, Professor of Entomology, The Ohio State University, for help in the preparation of the manuscript.

The larva is now crescent-shaped, with a spherical body destitute of spines. It possesses a rounded head followed by twelve segments, i.e., 3 thoracic and 9 abdominal, not counting the anal vesicle, which is well developed in this stage. The larva is more opaque and has a creamy color. The old skin or exuvium of the first-stage larva is attached to the posterior end of the last abdominal segment.

Third- (Last-) Stage Larva—(Pl. I. 6). The length after external feeding period is completed is 6.5 mm., the width 1.9 mm., mandible length 0.147 mm., and the average length of the large dorsal spines 0.098 mm.

Upon issuance from the host, the larva is cylindrical and possesses 14 body segments. The body is creamy in color and the skin is thickly covered with minute blunt spines. Dorsally on each of the abdominal segments 1–9, inclusive, are located a few long and dark-brown chitinized spines. These spines occur on each of the nine segments in two short, transverse rows, one on each side of the dorsomeson. Those spines on the dorsomeson have the greatest length.

There are rather large lateral lobes on the first 9 abdominal segments produced by the arrangement of the muscles in that part of the body. Eight spiracles are located on the lateral aspects and near the anterior margin of the second thoracic and first 7 abdominal segments.

After completing its external feeding, the larva is plump, with the lateral lobes distinctly swollen. The color varies from cream to light brown.

Pupa—(Pl. I. 7). The length of the pupa is 4.3 mm., and its width 1.6 mm.

The pupa is of the exarate type, with the legs, wings and antennae free. During this stage it exhibits no movement. For the first four or five days, about half of the pupal period, it is pale yellow in color. The color gradually darkens during the later half of the pupal stage.

Adult—(Pl. II. 8). The length of the imago is 4.1 mm., and its breadth with the wings extended is 6.7 mm.

It is black in color, with smoky wings. The antennae are filiform with sixteen segments in the female and twenty-three in the male. The abdomen is covered dorsally and laterally by a single hard, convex sclerite or carapace, which is creamy-white in its anterior half. At the extreme base of the carapace is a small, semi-circular black area. The carapace of the male has an apical oval foramen with a breadth of from 1.5 to 2 times the length, where the length equals the perpendicular height on the apex of the carapace. The body is punctured all over by irregular polygonal areas. Each area gives rise to a hair near its center.

BIOLOGY

Oviposition—If the eggs of *Ephestia* are exposed to the females of *Chelonella* for a period of 24 hours, eggs of the parasite will be deposited within the host eggs. The number of *Chelonella* eggs deposited within an egg of *Ephestia* varies according to the number of the host eggs exposed. When the *Ephestia* eggs are few in number, the number of *Chelonella* eggs deposited per host egg is large.

The *Chelonella* eggs hatch within the egg of *Ephestia*. The hatching period varies with the temperature. It takes 3 to 5 days at 20° C. and 2 days at 28° C. The hatching period of the host eggs (*Ephestia*) takes seven days at 20° C. and four days at 28° C.

Apparently all of the *Chelonella* eggs deposited within the host egg hatch. In some cases as many as nine larvae were dissected out of a single *Ephestia* egg, but only one survives (see section on larval development) and completes its development.

A pre-oviposition period or mating are not essential to egg-laying. The female *Chelonella*, upon emergence from the cocoon, has within her ovaries a number of well developed eggs, which she will deposit at once, if provided with host eggs.

A *Chelonella* female moving about in a cage containing a card of *Ephestia* eggs, appears to note the presence of host eggs when she is about one to two cm. from

them. She waves her antennae rapidly, rubs her body and hind legs with her wings, and approaches the eggs. Immediately the antennae are lowered with the tips flattened against the card containing the eggs. The antennae are pushed forward until they encounter the eggs and then the tips are brushed over the surface of one of the eggs. The female draws her body directly forward a short distance and at the same time unsheaths her short ovipositor and inserts it vertically into the egg. During oviposition the female stands motionless over the host egg with her antennae extended straight out before her and bent slightly downwards; the abdomen is at a 90° angle with the rest of the body and the wings on a straight line with the thorax and the head. The first movement following the deposition of the eggs are, a withdrawal of the ovipositor, straightening of the abdomen and a slight vibration of the antennae. The female then turns around, searching for another egg, and the process is repeated. This procedure is repeated until every egg on the card is parasitized or until the female has deposited all of the mature eggs contained in her ovaries, as verified by dissection.

Pierce and Holloway (1912), describing the parasitizing of eggs of *Laphygma frugiperda* (A. & S.) by *Chelonus texanus* Cress., mentioned the moving forward of the abdomen just prior to oviposition, and this was later confirmed by Luginbill (1928). A similar behavior was observed by Vance (1932) during the oviposition of *Chelonus annulipes* Wesm. in the eggs of *Pyrausta nubilalis* (Hbn.).

It takes from 10 to 25 seconds for a regularly ovipositing *C. sulcata* female to lay a number of eggs inside that of *Ephestia*. However, the process often takes several minutes. For example, one *Chelonella* female on her first day of oviposition, was observed to deposit 98 eggs inside 9 host eggs, spending an average of one minute and fifteen seconds at each oviposition. A maximum of three minutes and thirty seconds was required for one deposition and a minimum of ten seconds for another.

The age of the host eggs does not influence the choice of the female in her selection, nor does host egg age influence the development of the parasite.

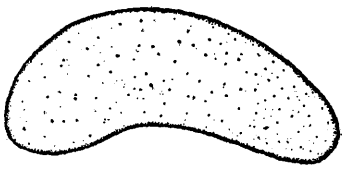
It has been observed that there is a direct relationship between the rate of oviposition of *Chelonella* and the amount of food consumed. It has been found that when a female *Chelonella* is deprived of food, which consists of honey placed as small drops in a row on each side of the midrib of a *Nerium* leaf, she does not oviposit the normal number of eggs. Whereas when the same female was supplied with ample food, the number of eggs oviposited was much greater.

The incubation of the eggs of *Chelonella sulcata* varies with the temperature, the higher the temperature, the shorter the incubation period and vice-versa. One day is the shortest incubation period between March and the end of November. This minimum period occurred in July, whereas the longest incubation period (5 days) occurred during the latter part of March and the beginning of April. Also, the average incubation period is four days during March, three days during

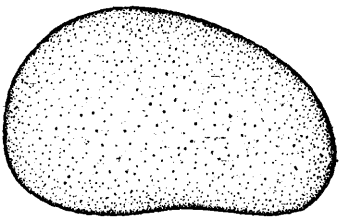
---

EXPLANATION OF PLATE I

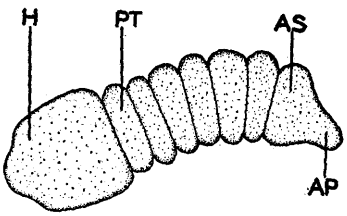
FIG. 1. Chelonella egg just after deposition inside host egg. Length, 0.154 mm.
FIG. 2. Chelonella egg just before hatching. Length, 0.154 mm.
FIG. 3. Dorsal view of first-stage larva just after hatching. AS, anal segment; AP, appendage; H, head; PT, prothorax. Length, 0.26 mm.
FIG. 4. Ventral view of 12-day old first-stage larva. AV, anal vesicle; H, head; LP, labial process; Mn mandible; PT, prothorax. Length, 0.8 mm.
FIG. 5. Lateral view of second-stage larva. AV, anal vesicle; H, head; LM, exuvium of first-stage larval moult. Length, 3.15 mm.
FIG. 6. Lateral view of last-stage larva. A, anus; FS, first abdominal spiracle; H, head; LL, lateral lobe; SS, seventh abdominal spiracle; TS, thoracic spiracle. Length, 6.5 mm.
FIG. 7. Lateral view of late pupal stage. Length, 4.3 mm.
FIG. 8. Dorsal view of adult *Chelonella sulcata*. Length, 4.2 mm. Width of wings stretched, 6.75 mm.



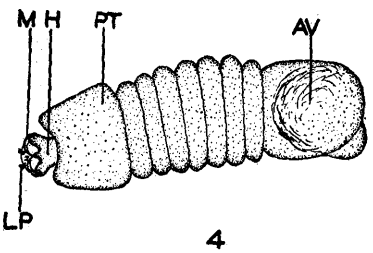
1



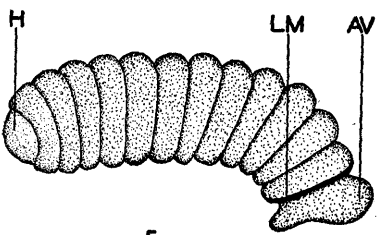
2



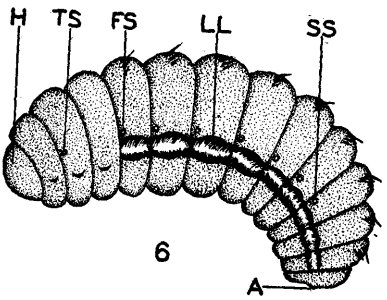
3



4

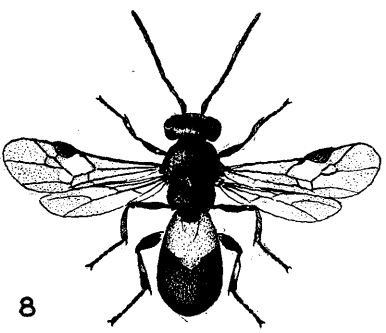


5



6

7



8

April, three days during May, two days during June, July, August, September and October, and three days during November.

Effect of Temperature on Oviposition—The temperature at which the females are kept influences oviposition. By working out the minimum and maximum temperatures at which no oviposition took place, it has been found that a temperature of 15° C. is the minimum and a temperature of 40° C. is the maximum. The number of eggs oviposited increased as the temperature rose. It was noted that the females kept at a temperature of 35° C. had died nine days earlier than those kept at 26° C. This indicated that high temperature shortens the life of the insect and also accelerates the rate of oviposition.

Larval Development—The larva of *Chelonella sulcata* is strictly an endoparasite which spends practically all of its life free within the body cavity of the host larva. A general idea of the advancement of the larval development is obtained from numerous host larva dissections coupled with a study of the body size, molted skin, form of the mandibles and widths of the head capsules.

The parasite passes through three distinct larval instars, moulting twice within the host, while the third moult takes place outside the host, within the newly-spun cocoon. The cast skins of the first and second moults are pushed back towards the posterior end of the larva, where they remain attached in the form of a thin dark ribbon at the base of the anal vesicle, especially in the case of the second-stage larva. In both larvae, they remain attached for a short time before they are entirely shed. The third moult takes place within the newly-spun parasite cocoon and can be easily seen at the posterior end of the white silvery cocoon.

The length of the larval stages varies considerably with the temperature. Under constant temperature of 27° C. dissection of about 90 *Ephestia* larvae of different ages containing *Chelonella* parasites showed the length of the larval stages to be approximately as follows: The first stage lasts 16 days, second stage 4 days, last stage (internal) one day and last stage (external) two days, or a total of 23 days. Considerable individual variation occurs in the length of the stages, especially among the first stage larvae for the six generations. Table I gives the average lengths of the three larval stages during the six generations per year.

The *Chelonella* larva of the sixth generation spends nearly three months of the year as a late first-stage larva within the hibernating host larva.

About 200 parasitized *Ephestia* larvae were placed at a constant temperature of 27° C. Nineteen *Chelonella* larvae emerged from these host larvae, averaging 25 days, counting from the time the parasite eggs were deposited until the issuance of the *Chelonella* larvae from the host. The pupation of 40 unparasitized host larvae subjected to the same temperature and reared at the same time, counting from the time the other host eggs were exposed to oviposition by *Chelonella* until the pupae were formed, required an average of 31.3 days. The *Chelonella* larvae had left their host larvae on an average of 6.3 days earlier than the latter normally pupated.

As has been noted before, *Chelonella* oviposits within the eggs of *Ephestia* and all of the eggs hatch within the host egg. As many as fourteen parasite eggs have been dissected from one *Ephestia* egg. When the host eggs hatch, not more than two parasite larvae can be found within the host. This condition does not last long, for within 24 hours after the *Ephestia* has hatched, only one of the *Chelonella* larvae survives. Great numbers of dissections have never shown more than one second-stage larva per host. Also in rearing many hundreds of individuals, not more than one mature parasitic larva has emerged from a single parasitized host.

Issuance of Last-Stage Larva and its External Feeding—Prior to issuance of the last stage larva of *Chelonella* from its host, the parasitized *Ephestia* larva spins a very loose, oval coooon which is strengthened in part by food particles of coarse

crushed maize (corn meal). About one-third of the cocoon is free of maize particles and remains a thin silky sheet through which the larva can be seen. The color of *Ephestia* larvae changes from yellowish-brown to creamy-white. It becomes plump and develops an appearance similar to that of an undersized prepupa. On dissection of such a parasitized larva, the third stage larva of *Chelonella* is seen lying with its ventral surface against the dorsal wall of the host larva. Also its head is directed cephalad to the *Ephestia* larva. After transforming into the last stage, the parasite larva remains from half to one day within the host larva. By means of its powerful dentated mandibles, it eats its way out through an incision in the dorsal integument of the host.

After making an incision in the dorsum of the host larva with its mandibles, the parasite larva protrudes its head from the opening, followed by the rest of the body. The head and body segments are directed towards the posterior end of the host larva. When all the abdominal segments are withdrawn from the host, the *Chelonella* larva begins its external feeding at some point on the dorsal surface

TABLE I

AVERAGE LENGTH OF THE THREE LARVAL INSTARS OF *Chelonella sulcata* DURING THE SIX GENERATIONS ANNUALLY

Generation Number	Average Temp. During Generation	Maximum Temp. During Generation	Minimum Temp. During Generation	Average Length of Time of			Average Length of Larval Stages	Maximum Duration of Larval Stages	Minimum Duration of Larval Stages
				First Stage Larva	Second Stage Larva	Third Stage Larva			
	In degrees centigrade	In degrees centigrade	In degrees centigrade	Days	Days	Days	Days	Days	Days
First	21.47°	27.0°	17.0°	31	5	3	39	45	38
Second	26.2°	29.5°	23.5°	28	5	3	36	40	35
Third	28.0°	29.0°	26.5°	18	4	3	25	25	24
Fourth	26.7°	29.0°	26.0°	16	4	2	22	24	22
Fifth	23.9°	28.0°	21.0°	44	5	3	52	64	36
Sixth	22.4°	23.0°	21.0°	83	5	3	91	96	88

near the caudal end of the host larva. Then it curls its head to the right or left, followed by the rest of the body segments, and moves slowly towards the cephalic end of the host larva. During its movement, it makes other incisions in the body and continues its feeding upon the internal organs of the host larva.

After completing its external feeding, which takes from 24 to 48 hours, nothing remains of the host larva except the empty skin and the chitinous exoskeleton of the head. The *Chelonella* larva becomes more rounded and when dissected, the peritrophic membrane is found full of pieces of the host trachea, fat, alimentary canal and other parts of the internal organs of the host larva.

Cocoon Formation—A few days before the last stage larva of *Chelonella* issues from the body of the host larva, the host spins a thinly constructed cocoon which some writers call the "death-cell." After the parasite larva finishes its external feeding, it rests quietly for about 24 hours. It then starts spinning its cocoon within this so-called death-cell of the host. The construction of the cocoon takes from a half to one day.

The cocoon is constructed of silk white threads, coming out of the external opening of the common silk duct situated on the upper border of the labium of the last-stage larva. The larva, during cocoon construction, moves its head upwards, downwards, forwards and backwards. The silk threads which emerge in a semi-liquid state are gradually woven into a silver-white papery cocoon.

This cocoon is loosely spun exteriorly, but more tightly woven towards the interior, and is attached by the outer threads to the "death-cell." The head capsule and dry skin of the host larva are found outside the cephalic region of the parasite cocoon between the latter and the "death-cell."

A number of experiments were made to determine the effect of external factors on the parasite larva during cocoon formation and pupation. If after its external feeding, the *Chelonella* larva is transferred from its place to a glass tube containing fresh, finely crushed maize, the larva being deprived of its host cell, does not spin its normal cocoon. Much silk comes out of the silk glands, and is woven around the larval head in an irregular fashion which produces a cap over the head. The larva does not live long, usually dying two days before it would normally pupate. In general, it can be said that any disturbance of the parasite larva when it is ready to spin a cocoon, upsets cocoon formation and produces an abnormal distribution of silk which in the end results in death.

Pupal Development—The cocoon of the parasite is spun in about 24 hours and, when finished, the larva ceases movement and rests quietly while transformation begins. One may observe with difficulty through the semi-transparent cocoon the changes the larva undergoes. The thorax and the head become distended and a slight constriction appears between the thorax and the abdomen. The eyes become pigmented and visible and the appendages also appear. This is the prepupal stage common to Hymenopterous parasites. Shortly thereafter, the meconium of the larva is expelled. The prepupal stage does not last more than a few hours and it is difficult to observe. The appendages of the pupa become more and more visible underneath the prepupal skin. The prepupal skin then splits from six to twelve hours after the casting of the larval meconium, beginning at the top of the head and slipping slowly posteriorly, revealing a pale yellow pupa with its perfect appendages. The casting of the larval meconium can be taken for practical purposes to indicate the beginning of the pupal stage. The emergence of adult *Chelonella* from the cocoon may be considered as the end of the pupal period, though the imago may remain within the cocoon a short time after it has been completely formed.

The *sulcata* pupa lies in the posterior two-thirds of the cocoon with its abdominal tip more or less submerged in the larval meconium which is a grayish-black semi-liquid substance located within the inner wall of the cocoon at its caudal extremity.

During development, the color changes of the pupa are distinct. During the first four or five days, or about half of the pupal period, it is pale yellow in color. During the latter half of the stage, the body darkens gradually. The eyes and ocelli in the early stages are light brown and gradually darken to brown. The antennae, head, thorax and the dorsum of the posterior half of the abdomen change from pale yellow to pale brown, to brown, and then become black. The legs also darken and the wings become smoky, with the stigma and wing veins dark brown. The somewhat protruded ventral part of the abdomen remains pale yellow in color in its anterior half, and the posterior half becomes dark brown. The ovipositor becomes brown-colored.

The effect of temperature upon pupal development is quite evident. A temperature of 8° C. serves to retard pupal development, and too long exposure to such low temperature apparently results in high mortality. An experiment was made to determine the exact length of time that *Chelonella* pupae might be subjected to a low retarding temperature and still obtain satisfactory emergence of adults after the cocoons were again exposed to higher temperatures. Fifty cocoons, containing prepupae or early pupae, were placed in a refrigerator at a constant temperature of 8° C. After 25, 30, 35, 40, and 50 days, ten cocoons were taken out, examined, and placed at a temperature of 27° C. The number

of adults that emerged were counted. It is evident from this experiment that most of the pupae remain in an early state of development during their exposure to the low retarding temperature. It appears that 40 days is the maximum length of time that *Chelonella* pupae may be subjected to 8° C. and still emerge after their cocoons were exposed to the higher temperature of 27° C.

Emergence of Adult—Inside the cocoon the black-colored adult is indistinctly visible through the semi-transparent silvery cocoon wall. A cocoon just prior to adult emergence was observed under a binocular microscope. The adult *Chelonella* is oriented with its head a few mm. from the anterior end of the cocoon. When about to emerge, frequent movements of the legs, antennae and wings take place, followed by a pushing forward of the whole body of the insect until the head comes close to the cocoon wall. Then the mandibles of the adult insect begin to tear away the silk threads at the tip of the cocoon. This cutting process continues until a hole is made wide enough for the emergence of the body. The insect then shoves its way gradually through this opening. The head protrudes first, followed by the thorax and then the abdomen. The newly emerged adult is quite dry, vivid, and moves actively about inside the glass vial. The cast meconium of the last larval stage and pupal skin may be found at the opposite end of the cocoon. Adults may emerge anytime during the day or night.

Feeding—Various materials have been tested as food for the adults, including sugar lumps, honey, and sugar solutions in soft cotton. Honey proved to be the most successful food for *Chelonella*.

Parthenogenesis and Unisexual Reproduction—It has been found that fertilization in female *Chelonella sulcata* is neither a stimulus nor an absolute condition for oviposition. Unmated females oviposit readily and all their progeny are females. In all of the breeding tests no males were seen. Generation after generation always produced females. This indicates a state of unisexual reproduction in which females always produce females without the intervention of males. This phenomenon occurs frequently among the parasitic *Hymenoptera*. Unisexual reproduction is normal in a number of species of *Braconidae*, among which may be mentioned *Apanteles thompsoni* Lyle, *Roges unicolor* Wesm., *Meteorus japonicus* Ashm., and *Microctonus brevicollis* Hal. Not a single male of *Apanteles thompsoni* Lyle has ever been secured in the large-scale rearings that were made by Vance (1931). Under laboratory conditions, all rearings produced females only. Green cotton bolls collected from the field of the Giza experiment station were brought into the insectary until the parasites emerged. Of 100 *Chelonella sulcata* adults collected, two were males and the remainder females. The two males were placed with two females in glass vials and were subjected to artificial strong light for six hours at 27° C. to encourage mating. Copulation was seen to take place and *Ephestia* eggs were then exposed to these mated females. They oviposited normally in these eggs and the host eggs were reared until the adults of *Chelonella* emerged and all were females. In other words, we have an example of a class of insects in which females are produced almost constantly and the opposite sex is rarely encountered. This type of reproduction among parasitic *Hymenoptera* is known as "thelytoky."

Adult Longevity—Chelonella sulcata adults are hardy insects. Forty-eight freshly emerged adults confined in separate glass vials covered with muslin, were subjected to various temperatures and food conditions and observed daily. The data obtained from these observations are shown in Table II. Temperatures 8° C., 15° C. and 30° C. were electrically controlled and were practically constant. The room temperature was that of the laboratory, which ranged between 20° C. and 28° C. while the experiments were in progress. The food consists of honey. Water was provided daily by a water-soaked cotton wick placed in the bottom of the glass vials. The results show that *no* food or water produced the shortest

longevity (2 to 5 days), while tests with food and water provided optimum longevity (10 to 33 days). Tests with food alone, 6 to 15 days, and with water alone, 4 to 8 days, gave intermediate results.

The noticeable effect of temperature was a shortening of the life of the individuals kept at 8° C. and supplied with both food and water. Laboratory temperatures which fluctuated around 26° C. at the time of the experiment were very favorable to longevity, provided the adults were given both food and water.

Effect of Parasite on Host—Externally, there appears to be no distinguishable difference between parasitized and non-parasitized host larvae up to and including the third instar. After the third instar, the non-parasitized larvae grow more rapidly and are larger than the parasitized individuals. It has been found that the average length and breadth of non-parasitized larvae is 13.5 and 2.5 mm., and that of parasitized larvae is 6.45 and 1.35 mm. This means that the parasitized larva is smaller in size than the non-parasitized by an average of 7.05 to 1.15 mm.

TABLE II

EFFECT OF VARIOUS TEMPERATURES AND FOOD CONDITIONS ON THE LONGEVITY OF ADULT *Chelonella sulcata*

TEMPERATURE	WITH FOOD AND WATER		WITH FOOD ALONE		WITH WATER ALONE		WITH NO FOOD OR WATER	
	Individuals	Average	Individuals	Average	Individuals	Average	Individuals	Average
	Days	Days	Days	Days	Days	Days	Days	Days
8° C.....	10, 12, 18	13.3	9, 8, 6	7.6	5, 6, 4	5	4, 5, 2	3.6
15° C.....	20, 25, 19	21.3	8, 12, 11	10.3	6, 8, 5	6.3	3, 4, 3	3.3
30° C.....	28, 26, 22	25.3	10, 11, 9	10	7, 5, 8	6.6	2, 3, 4	3
Room.....	33, 31, 29	31	12, 15, 14	13.6	8, 6, 7	7	3, 2, 5	3.3

*Each of these numbers represents the longevity of one individual confined in a separate glass vial.

The parasite not only effects the size of the host, but also retards its development. In the summer generations, which extend from April to the end of November, the non-parasitized larvae continue their development into the sixth or last larval instar and pupate normally. Those larvae of the same generations, which contain *Chelonella* larvae are so retarded in growth that the parasites issue before the *Ephestia* larvae have entered the last instar. In the winter generation, which lasts from the end of November to the middle of March, both the non-parasitized and parasitized larvae hibernate. The non-parasitized host larvae hibernate as the last instar, and the parasitized individuals hibernate as fourth-instar larvae and are smaller in size than the normal host larvae. During this generation, the parasitized host larvae can be easily separated from the non-parasitized by their size.

The color of the parasitized larvae is pale yellow, and differs from that of the non-parasitized individuals, which are buff-colored.

The parasitized host larva during its inactive stage is enclosed and lies motionless in a light woven cocoon. The third or last stage larva of the parasite finds its way out of the host larva and begins its external feeding, eventually leaving only the shrunken cuticle and chitinized head-parts of the host.

Not a single host larva lived after the emergence of the *Chelonella* last-stage larva. This conclusion was also reached by Vance (1931), in the case of *Apanteles thompsoni* Lyle, parasitic on *Pyrausta nubilalis* (Hbn.) where he said "death is the fate of any larva of *Pyrausta nubilalis* from which *Apanteles* larvae have issued, and in no known instance has pupation of the host followed."

Life History and Number of Generations—The life history of *Chelonella sulcata* was taken from records made under laboratory conditions. *Ephestia kuehniella* was the host used in the laboratory for rearing the parasites. It was found that the life-cycle of *Chelonella* is dependent to a considerable extent upon the rate of development of the host. The number of generations of the parasite corresponds to that of its host. The experiments made during 1943 and 1944 showed that the *Chelonella* female began oviposition directly after emergence, provided it was supplied with eggs of *Ephestia*. If we take the middle of March

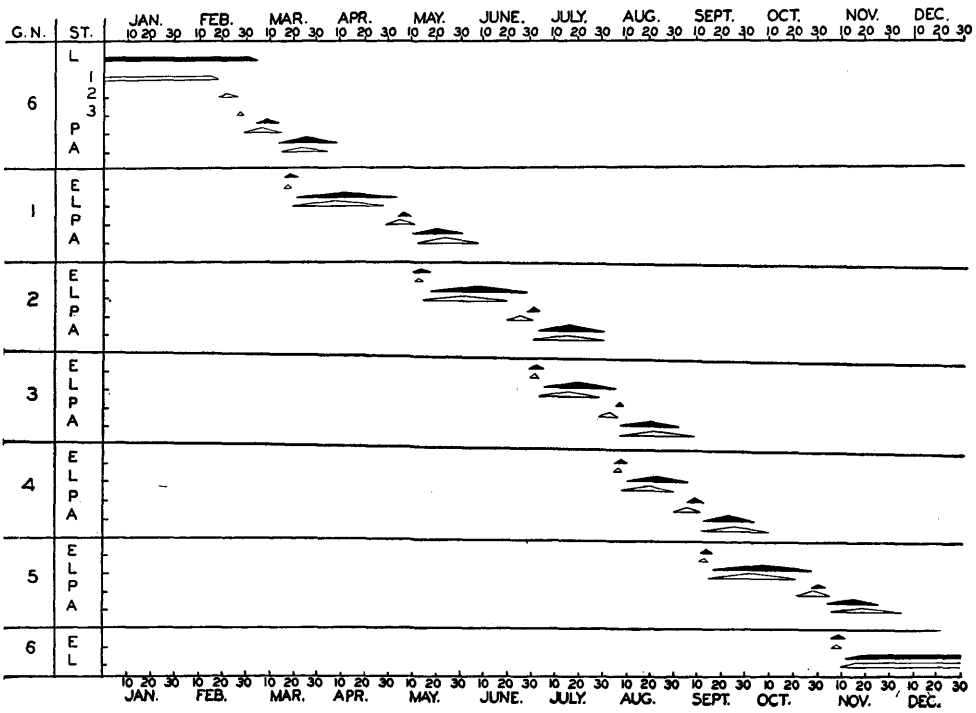


FIG. 1. The duration of stages of both *Chelonella sulcata* Nees (parasite); *Ephestia kueheniella* Z. (host) during the six generations per year and the longevity of the adult in each generation. Host in dark areas.

as a point when the adult parasite comes out from the hibernating larva, and December 5th as the date the parasitic females cease ovipositing, we obtain as many as six generations.

The relationship between the life history of the parasite *Chelonella* and its host *Ephestia* is clearly demonstrated in Fig. 1, made from data of daily observations over a two-year period.

LITERATURE CITED

(1) **Clausen, C. P.** (1940). Entomophagus Insects. McGraw-Hill Book Co., Inc., N. Y. and London. 688 pp., illus.

(2) **Derril, Daniel.** (1932). *Macrocentrus ancylivorus* Rohwer, a polyembryonic braconid parasite of the Oriental Fruit Moth. N. Y. State Agri. Exp. Sta. Tech. Bull. 187, 101 pp., illus.

(3) **Imms, A. D.** (1937). Recent Advances in Entomology, 2nd Edition. Churchill Ltd., London.

(4) **Imms, A. D.** (1938). A General Text-book of Entomology, 4th Edition. Methuen & Co. Ltd., London.
(5) **Luginbill, P.** (1928). The Fall Army Worm. U. S. D. A. Tech. Bull. 34. 92 pp., illus.
(6) **Marshall, T. A.** (1888). Les Braconides. 603 pp., illus.
(7) **Parker, H. L.** (1931). *Macrocentrus gifuensis* Ashmead, A polyembryonic brachonid parasite in the European Corn Borer. U. S. D. A. Tech. Bull. 230, 63 pp., illus.
(8) **Pierce, W. D.,** and **Holloway, T. E.** (1912). Notes on the biology of *Chelonus texanus* Cress. Journ. Econ. Ent. 5: 425–428.
(9) **Szepligeti, V.** (1908). Braconiden aus des sammlung des Hungarischen National Museum. Ann. Hist. Nat. Mus. Nat. Hung., Vol. VI, pp. 403–405.
(10) **Vance, A. M.** (1931). *Apanteles thompsoni* Lyle, a braconid parasite of the European Corn Borer. U. S. D. A. Tech. Bull. 233, 28 pp., illus.
(11) **Vance, A. M.** (1932). The biology and morphology of the braconid *Chelonus annulipes* Wesm., a parasite of the European Corn Borer. U. S. D. A. Tech. Bull. 294, 48 pp., illus.
(12) **Vickery, R. A.** (1929). Studies on the Fall Army Worm in the gulf coast district of Texas. U. S. D.A. Tech. Bull. 138, 64 pp.
(13) **Wilkcocks, H. C.** (1916). The insects and related pests of Egypt, Vol. I, part 1, plate V, fig. 14. Lancioni, Cairo.
(14) **Wilkinson, D. S.** (1932). Some new species of *Chelonella* (*Hymenoptera—Braconidae*) Stylops. London 1, pp. 6–10, 2 figs.